Beam Single Spin Asymmetries in SIDIS from an Unpolarized Proton

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Abstract. Semi-inclusive deep-inelastic scattering (SIDIS) is a useful tool for studying the dynamics of quarks inside the nucleon. Measurements of pion electro-production in SIDIS have been performed. Data were taken with the CEBAF Large Acceptance Spectrometer (CLAS) at Jefferson Lab using a 5.5 GeV longitudinally polarized electron beam and an unpolarized liquid hydrogen target during the E1-f run period in 2003. All three pion channels (π^+, π^0 and π^-) were measured simultaneously over a large range of kinematics ($Q^2 \approx$ 1-4 GeV^2 and $x \approx$ 0.1-0.6). Single-spin azimuthal asymmetries from all three pion channels were measured as functions of x, z, P_T, and Q^2, from which $A_{LU}^{sin\phi}$ was extracted. $A_{LU}^{\sin\phi}$ is a twist-3 structure providing information about quark-gluon-quark correlations. This new high statistical data will provide an important means of studying transverse degrees of freedom in the nucleon.

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INTRODUCTION

We are measuring pion electroproduction in semi-inclusive deep inelastic scattering (SIDIS) using the CLAS detector at Jefferson Lab. Measurements are performed of the $sin\phi$ moment, $A_{LU}^{sin\phi}$ for all three pion channels in the semi-inclusive reactions $ep \rightarrow e\pi^{\pm,0}X$ from a single dataset. The moment is extracted from fits to beam single-spin asymmetries (BSSAs) as a two-dimensional function of P_T and x.

For the CLAS kinematics, the cuts used to identify SIDIS events are as follows. Cuts on $W > 2$ GeV and $Q^2 > 1$ GeV^2 identify events in the deep inelastic region, and cuts on $z < 0.7$ and $M_X > 1.2$ GeV help to remove exclusive events. Also a cut on $z > 0.4$ is used to ensure that the events measured are not in the current fragmentation region.

Assuming single-photon exchange, the SIDIS cross section given in Eq. 1 may be expressed as a function of ϕ_h, the angle between the leptonic and hadronic scattering planes [1].

$$d\sigma = d\sigma_0(1 + A_{UU}^{\cos\phi}\cos\phi + A_{UU}^{\cos 2\phi}\cos 2\phi + \lambda_e A_{LU}^{\sin\phi}\sin\phi) \tag{1}$$

Here the beam helicity is denoted by $\lambda_e = \pm 1$. The $A_{LU}^{sin\phi}$ term can then be extracted by measuring the asymmetry of events from each of the two helicity states.

The $sin\phi$ moment is a purely twist-3 object providing information on quark-gluon-quark correlators in the proton. $A_{LU}^{sin\phi}$ can be related to structure functions by the relation

$$A_{LU}^{\sin\phi} = \frac{F_{LU}^{\sin\phi}}{F_{UU,T}} \tag{2}$$

where $F_{UU,T} = C[f_1 D_1]$ and

$$F_{LU}^{\sin\phi} = \sqrt{2\varepsilon(1+\varepsilon)}\frac{2M}{Q}C[-\frac{\hat{\mathbf{h}}\cdot\mathbf{k_T}}{M_h}(xeH_1^{\perp}+\frac{M_h}{M}f_1\frac{\tilde{G}^{\perp}}{z})+\frac{\hat{\mathbf{h}}\cdot\mathbf{p_T}}{M}(xg^{\perp}D_1+\frac{M_h}{M}h_1^{\perp}\frac{\tilde{E}}{z})] \tag{3}$$

$F_{LU}^{sin\phi}$ contains a rich trove of information concerning the transverse structure of the proton [2], given in four pairs of convoluted functions. Here $e(x)$ is a twist-3 parton distribution function and $H_1^{\perp}$ is the naive time-reversal odd Collins fragmentation function [3] which has previously been seen to exhibit opposite deflection of charged pions at Belle, HERMES, and COMPASS. $g^{\perp}$ is the twist-3 T-odd distribution function. It may be easier to extract $g^{\perp}$ from A_{LU} of π^0s because of flavor cancellation in the Collins function. $\tilde{E}$ and $\tilde{G}^{\perp}$ are twist-3 fragmentation functions, and $h_1^{\perp}$ is the leading-order TMD parton distribution, known as the Boer-Mulders function [4].

EXPERIMENTAL PROCEDURES

Data was taken using the CLAS detector at JLab during the E1-f run period from April until July of 2003. The experiment utilized a longitudinally polarized electron beam with a beam energy of 5.5 GeV and polarization of 75±3% with an unpolarized liquid hydrogen target. The CLAS torus magnet was reduced to 60% of its nominal current to maximize acceptance of charged pions, in particular π^- that would usually be bent out of the range of CLAS acceptance. An integrated luminosity of 21 fb^{-1} was collected during the experiment.

The BSSA is calculated as shown in Eq. 4 in each bin in x, P_T, and ϕ, and then fit with the function $\frac{Asin\phi}{1+Bcos\phi+Ccos2\phi}$ to measure $A_{LU}^{sin\phi}$.

$$BSA = \frac{1}{P_e}\frac{N^+ - N^-}{N^+ + N^-} \tag{4}$$

Systematic uncertainties are determined by systematically varying each cut used to select good events in the particle identification routines for electrons and pions, as well as the methods of background subtraction used in the π^0 identification. An asymmetry of the subtracted background was also measured and included in the systematic error. The fitting function was varied to identify any changes in $A_{LU}^{sin\phi}$ stemming from a slightly different fit. After all variations, the total systematic error is measured to be of similar magnitude to the measured statistical uncertainties.

PRELIMINARY RESULTS

Preliminary results are shown for $A_{LU}^{sin\phi}$ vs x in each of five bins in transverse momentum in Fig. 2. The data is binned with five bins in x from 0.1 to 0.6, five bins in P_T from 0 to

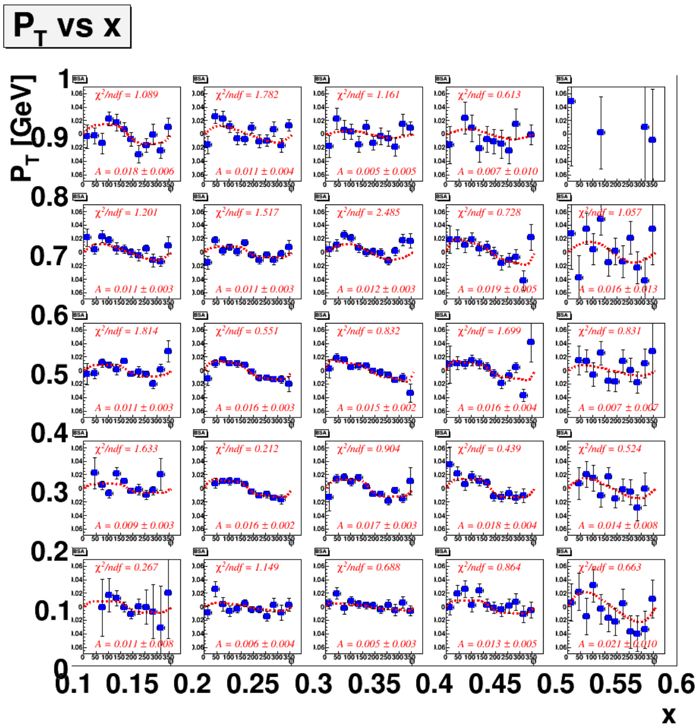

FIGURE 1. Fits to the BSSAs binned in P_T and x. The fit function used is $\frac{Asin\phi}{1+Bcos\phi+Ccos2\phi}$, where the coefficient A is extracted as the $sin\phi$ moment.

1 GeV, and twelve bins in ϕ.

In order to compare to previously published data from HERMES, the data is integrated over P_T and plotted against x only, as shown in Fig. 3. A comparison is also made to a model calculation that takes into account the contribution to $A_{LU}^{sin\phi}$ from only the $e(x) \otimes H_1^{\perp}$ term in the structure function [5].

This work provides an update to the results previously shown in [6] by adding π^0 results and showing dependence on x and adding multi-dimensional binning. Particle id routines and kinematic corrections were refined and systematic errors were computed.

CONCLUSION

Preliminary results are shown for $A_{LU}^{sin\phi}$ in all three pion channels. It is seen that $A_{LU}^{sin\phi}$ is positive for π^+ and π^0, but negative for π^-. The date is seen to be in good agreement with previous results from CLAS for π^+ [7] and π^0 [8], as well as from HERMES in all three channels [9].

These results provide a significant kinematic extension and higher statistical precision than the previously published data. Measurements of $A_{LU}^{sin\phi}$ provide a measurement of a purely twist-3 object, and will provide an improved understanding of quark-gluon-quark correlations in the nucleon.

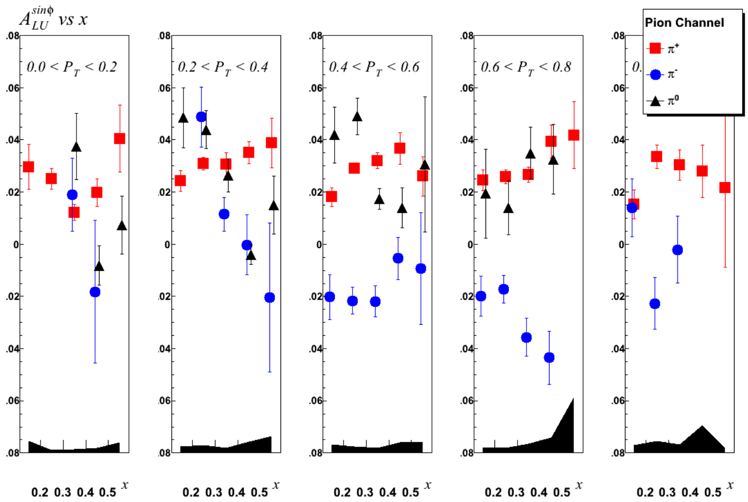

FIGURE 2. Preliminary $A_{LU}^{sin\phi}$ vs x in each of five bins in transverse momentum. The square (red) points are π^+, the round (blue) points are π^-, and the triangular (black) points are π^0. The shaded region gives an estimate of the systematic error in each bin.

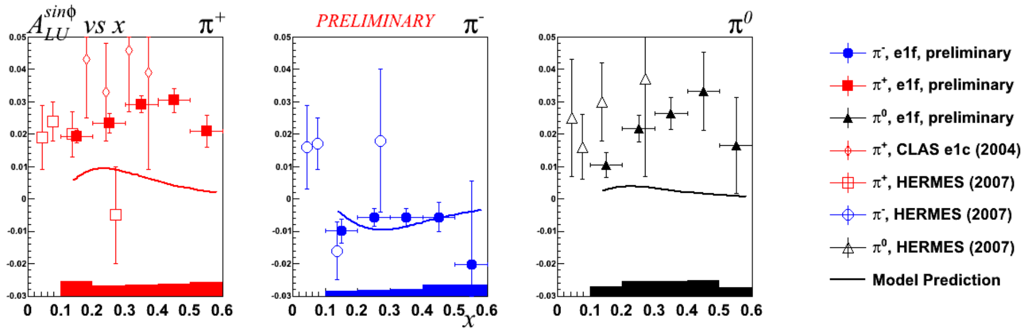

FIGURE 3. Preliminary data is integrated over P_T for comparison against previously published results from HERMES and CLAS. A model that takes into account only the contribution to $A_{LU}^{sin\phi}$ from $e(x) \otimes H_1^{\perp}$ is also shown.

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